University of Alberta

A Constructivist Approach to Computer-Based Learning

by

Georgia Katz

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Education

in

Instructional Technology

Department of Educational Psychology

Edmonton, Alberta

Fall 1996

National Library of Canada
Acquisitions and Bibliographic Services Branch
395 Wellington Street
Ottawa, Ontario
K1A 0N4

Bibliothèque nationale du Canada
Direction des acquisitions et des services bibliographiques
395, rue Wellington
Ottawa (Ontario)
K1A 0N4

Your file *Votre référence*

Our file *Notre référence*

The author has granted an irrevocable non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of his/her thesis by any means and in any form or format, making this thesis available to interested persons.

L'auteur a accordé une licence irrévocable et non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de sa thèse de quelque manière et sous quelque forme que ce soit pour mettre des exemplaires de cette thèse à la disposition des personnes intéressées.

The author retains ownership of the copyright in his/her thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without his/her permission.

L'auteur conserve la propriété du droit d'auteur qui protège sa thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

ISBN 0-612-18206-1

Canada

University of Alberta

Library Release Form

Name of Author: Georgia Katz

Title of Thesis: A Constructivist Approach to Computer-based Instruction

Degree: Master of Education

Year Degree Granted: 1996

Permission is hereby granted to the University of Alberta Library to reproduce single copies of this thesis and to lend or sell such copies for private, scholarly, or scientific research purposes only.

The author reserves all other publication and other rights in association with the copyright in the thesis, and except as herein before provided, neither the thesis nor and substantial portion the of may be printed or otherwise reproduced in any material form whatever without the author's prior written permission.

August 20, 1996

14712 59 Avenue

Edmonton, Alberta, Canada

T6H 4T6

August 20, 1996

University of Alberta

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis, entitled A Constructivist Approach to Computer-Based Learning, in partial fulfillment of the requirements for the degree of Masters of Education, in Instructional Technology.

Dr. R. H. Short
Thesis Supervisor

Dr. R. F. Mulcahy

Dr. Beth Young

Dr. George Buck

Date July 23, 1996

In loving memory of my parents, whose respect for education has always been an inspiration to me.

Abstract

Two questions are addressed in this study; 1) Can the computer serve as a cognitive tool? 2) Can the tenets of constructivism serve as a conceptual framework for computer-based instruction? A computer-based program, Canada Meets the World which included with this document, provides instruction in Chinese culture utilizing constructivist tenets. Cultural information in topical format is used to solve simulation and vignette problems. In a constructivist, computer-based environment, the learner can become actively involved in the personal construction of information while using the support of the computer to aid and focus analytical processes.The computer can provide the learner with the potential for enhancement of working memory capacity while providing the means for rapid retrieval and rapid organization of information. Since this study focused on the design of computer-based instruction, further work is needed to empirically test the learning efficency of the constructivist approach to instruction.

Acknowledgements

I would to thank Dr. Robert Short, and Dr. George Buck my thesis supervisors for their academic guidance and patience throughout this project.. During the development of Canada Meets the World, Dr. Buck's technical expertise was invaluable. I also thank the the other members of my committee, Dr. Beth Young, and Dr. R. Mulcahy,for their contributions.

Special thanks to Donna Frose for the pictures of China which she took while teaching in China and kindly allowed me to use.

To my family, I'd like to say thank you. A very special thank you to Malcolm, my son, for his practical assistance and encouragement throughout this project.

Table of Contents

Chapter 1: Introduction 1

Problem Statement 1

Significance of Study 1

Definition of Terms 2

Chapter 2: Review of Related Literature 5

Historical Background 5

Theoretic Evolution of Constructivism 7

Emergence of Constructivism 11

Constructivism: A theory of learning 13

Constructivism: Structure for computer-based Instructional Design 14

Theoretic Implications 19

Tools that support learning 20

Chapter 3: Research Method 24

Chapter 4: Discussion 35

Implications for further study 36

References 38

Appendix 41

List of Figures

Figure 1. Portion of an Authorware flow chart.....25

Figure 2. JumpOut Return 26

Figure 3. Example of Learning Tool 27

Figure 4. Sample Page from the China Information Section.....29

Figure 5. Time for Reflection.....29

Figure 6. The Village 31

Figure 7. Vignette 32

Figure 8. Culture Chart.....33

Chapter 1

Introduction

Problem Statement

The purpose of this study was to design a computer-based lesson on Chinese culture. The structure of this lesson demonstrates, not only how constructivism can be used as a theoretic framework for computer-based instructional design, but also how the computer can be employed as a learning tool congruent with this paradigm.

Significance of the Study

As the demand intensifies for the development of alternative instructional methods and as distance learning becomes a more practical means of instructional delivery, a need arises for varied and possibly more effective design of computer-based instruction. The computer, as a learning tool, has not been developed to its fullest potential. Although the computer is presently used as an effective medium for information presentation, learner feedback and evaluation, its potential, as a cognitive tool for learning remains to be realized. "Cognitive tools should activate cognitive and metacogitive strategies. They (cognitive tools) engage generative processing of information" (Jonassen, 1990, p. 2). Generative knowledge processing is accomplished by the learner through a constructive process. Specifically, information is interpreted, assimilated or reorganized, and consequently used as a basis for future interpretations and knowledge acquisition.

Through the design of a constructivist, computer-based environment, the learner can become actively involved in the personal construction of information while using the support of the computer to aid and focus analytical processes. This instructional technique

should lead to active manipulation and organization of information, and therefore, individual awareness of that learning process which best provides durable, personal learning.

The computer can provide the learner with the potential for enhancement of working memory capacity. The major constraint upon working memory is its limited capacity to store information. Typical memory span tests show that between five to seven digits is the average capacity of working memory. A second problem with working memory is the rapid decay of unrehearsed information once this information is no longer present in the learner's environment. With the aid of the computer, the learner can rapidly access stored information . By using the computer as a cognitive tool,working memory can be extended. The computer also has the capacity to retrieve, store and organize information at speeds far greater than the human capability while serving to provide the learner with the means to establish interrelationshps between ideas. When more interrelationships between ideas are developed by the learner, deeper information processing results. This process increases the potential for effective retrieval of information from long term memory.

Definition of Terms

Anchored instruction or situated learning - Instruction within a meaningful context which allows students and teachers to find and understand types of problems within a contextual environment so that they may experience the effects which this learning has on their perception and understanding (Cognitive and Technology Group at Vanderbilt University, 1992).

Bracketing - The definition of personal presuppositions, inferences and stereotypes about a particular group. This exercise provides knowledge baseline for personal cultural beliefs of a specific culture.

Cognitive tools - Mental and computational devices that support, guide and extend the thinking processes of their users and engage the learner in meaningful cognitive processing of information (Jonassen. 1990).

Computer-based instruction (CBI) - Computer-based learning represents a continuum of systems which support individualized tutoring, computer assisted instruction at one end and intelligent computer assisted instruction at the other end where decision making is the result of the use of principles by the program as opposed to preprogrammed responses and where analysis of learner response is based upon solution histories made within exploratory environments. Computer-based instruction lies near the mid-point of this continuum (Alessi & Trollip, 1991).

Concept mapping - A study technique of graphically representing concepts and concept interrelationships in a two dimensional format (Bayerbach, 1988).

Constructivism - In this study represents a conceptual design structure which supports active, generative and collaborative learning. Learning is embedded in the context of real situations and an open ended learning system is utilized.

Generative learning - A process which involves relating new information to prior knowledge in order to build more elaborate knowledge structures. The learner must engage actively in the mental processing of perceptions (Alessi & Trollip, 1991).

Hypertext - A color coded computer screen area, which when clicked, electronically links the user to a related field of information. The user is presented with a collection of information nodes with which to browse in a personal way (Draper, 1992).

Open learning system - A need driven, learner-initiated and conceptually and intellectually engaging learning environment.

Multiple perspectives - A refers to a variety of interpretations for the same idea (Jonassen, 1991).

Simulation - In this study represents a computer-based environment in which the student identifies and solves a problem in a context which is similar to the real world, but withless fidelity than the actual situation. The use of simulations are a good precursor to real experiences while providing a cost effective and safe environment (Alessi & Trollip, 1991).

Chapter 2

Review of Related Literature

Historical Background

Major educational reforms occurred in the early years of this century through the influence of such thinkers as Thorndike and Dewey. These reforms received renewed impetus as a result of Skinner's application of behaviorism to education in the 1950s, and in response to the development of cognitive science in the 1970s. Various types of behaviorism became the framework for instruction in the 1930s and this instructional theory has continued to influence educators today. Behaviorism is based largely on an objective world view. Behaviorists contended that learning may be studied by systematically observing behavior in response to environmental variables which are controlled and may be manipulated by the teacher, instructor or even a machine. Empirical research methods were used to study learning. Instructional design based on the behaviorist model has three underlying assumptions: that instructional prototypes will always be an effective teaching device after pilot testing is completed; that knowledge is taught through an atomistic approach based upon task analysis of complex activities and therefore, knowing how to do something depends on knowing how the pieces fit together; and that human behavior is predictable (Winn, 1991).

Learning was defined by Skinner as a more or less permanent observable change in behavior. Skinner's instructional views were based on a variety of behaviorism known as operant conditioning. His instructional method is organized into three stages: analysis, design and evaluation. Learning evolves from input through the control of stimuli and from the manipulation of consequences such as reinforcement or punishment which follows the learner's behavior. Cooper (1993) stated that behaviorists now feel that the potential behavioral changes are heavily influenced by both proactive and retroactive stimuli.

Cognitive theory was central to the educational reforms of the 1970s. Cognitive theory emerged, not from an objective view, but from a subjective perspective. Specifically, the development of knowledge stems from the idea that the mind neither copies reality nor inherently understands it. This idea was developed from the writings of Kant which later provided an epistemological basis for cognitive learning theory. According to Kant, the mind produces mental models that explain to the individual what has been perceived (Cooper, 1993). Mental models are not driven by external contingencies. The epistemological assumption which flows from this idea is that meaning is a function of how the individual interprets experience. Humans are perceivers and interpreters. The locus of learning is internally centered within the mind. What we know, we map onto past knowledge and this determines how we perceive the interactions with our environment. The external world is meaningless and is only known to an individual through the manner in which that individual perceives this external environment.

Cognitive psychologists believe that concept acquisition results, not only from environmental manipulation, but also from perception. Within cognitive science, perception is defined as active, constructive, selective, and schema driven. West et al. (1991) stated that "perception is primarily the construction of meaning via massaging the new with the old, within the schemata available and activated by an event" (p. 9). Learning, which is an internal process modified by perception, results from the encoding of information initially in working memory and finally into long term memory. Cognitive theorists infer the dynamics of the internal process of knowledge acquisition, of retrieval of learned information and also of transfer and generalization of this information. The goal of instruction from a cognitive perspective is to replicate knowledge structure and the way in which this knowledge is internally processed.

The shift from behaviorism to cognitive science represented a major change in the thinking of psychologists and educators alike. While behavioral views stressed the importance of the environmental factors on learning, cognitive accounts concerned

themselves with the learning process within the internal workings of the mind. West et al. (1991) noted six major fronts which were involved in the evolutionary shift from behaviorism to cognitive science:

> From dealing with behavior to dealing with internal representation; from dealing with parts to the representation of wholes; from concrete to abstract representations; from information as discovery and retrieval to information as construction or reconstruction; from the mind as an assembly line to mind as a computer; and from learning outcomes to learning processes (p. 12).

Theoretic Evolution of Constructivism

Piaget envisioned a series of stages by which he explained human intellectual development and he drew a parallel between intellectual development and biological epigenesis. According to Jacob (1984), Piagetian stages are characterized by "a process of progressive, unique and unalterable changes in the structure and action of thought" (p. 50). The order of appearance of these stages, but not the tempo of achievement, are invariant. This view is also accepted by neopiagetians, although some like Arlin (1975) added an additional cognitive stage for the period of young adulthood. Moreover, the speed of intellectual development can differ within and between cultures. Learning occurs within each developmental stage. Progress through Piagetian stages is characterized by a gradual migration in knowledge acquisition from a concrete to a more abstract and internalized structure. Piaget, according to Jacob, argued that learning was a function of development, i.e., learning is determined by cognitive development (p. 59).

Piaget refined the understanding of knowledge construction. He explained knowledge construction or learning in terms of assimilation and accommodation processes which were used to form and maintain a state of equilibrium between internal and external

forces. Learning stems from the inherent need of the individual to organize information in that way which produces balance or equilibrium. Piaget (1985) argued that "equilibrium referred to a process that leads from a state near equilibrium to a qualitatively different state of equilibrium by way of multiple disequilibrium and re equilibrium" (p. 3). This need to establish equilibrium forms the basis for constructivism. The motivational force of learning, and therefore, the catalyst for change, is the state of disequilibrium which is an internal process. Since learning takes place by the alleviation of disequilibrium, learning is an active process which requires information to be presented in a variety of ways and to be tested against the learners frame of reference. According to Piaget (Grubbier & Voneche, 1977), the basic structure for mental operations was termed schema. When these schemata are modified, accommodation had occurred and when new schemata are added to existing ones, assimilation had occurred. According to West et al. (1991), "Schemata are like packets or bundles in which the mind stores knowledge: they are patterns, structures and scaffolds" (p. 7). Cognition is an active process. Moreover, knowledge is internally organized and manipulated in an active way by the individual and is not the result of the passive reception of information from external sources. Therefore, from a Piagetian point of view, learning develops as a result of biological maturity, social experience, alleviation of disequilibrium and active engagement in the learning process.

Papert (1980), a student of Piaget and his ideas, worked to develop a machine capable of artificial intelligence which could be used to probe deeply into the nature of learning. Contrary to traditional Piagetian thinking, he believed that the separation between the learning process and what is learned was a mistake. Papert stressed an interest in a child's developmental potential as opposed to present developmental level, and the design of a learning environment that would be resonant with them. For example, Papert developed the Turtle, a mechanical device which was later reduced to an iconic representation of a triangle on the screen. The turtle was used as part of a computer micro world called Logo where mathematical principles were not represented but evolved through manipulation and

organization of information within this environment. According to Papert, "learning consists of building up a set of materials and tools that one can handle and manipulate" (p. 173). Therefore, the laws of learning must be about intellectual structures and how they logically emerge from previous structures. Learning and development are directly dependent upon the availability to the learner of those materials from within the culture which are needed to make a concept concrete. Cross cultural differences were explained in this manner by Papert. "Like other builders, children appropriate to their own use materials they find about them, most saliently the models and metaphors suggested by the surrounding culture" (p. 19). These ideas were in opposition to Piaget's. For Piaget, development and learning followed a biologically regulated progression toward increasing complexity.

How can Piagetian ideas be applied to adult learning? An examination of Mezirow's theory of transformative learning conveys additional insight into the dynamics of learning as described by Piaget. Mezirow (1978) developed his theory to explain how adults learn based upon the idea that some adult learning entails critical analysis of their personal paradigms. All adults have a system of beliefs based at least in part upon their personal history and these beliefs must be examined so that learning can occur. Mezirow (1981) stated that, "A cardinal dimension of adult development and the learning most uniquely adult pertains to becoming aware that one is caught in one's own history and is reliving it" (p. 3). Although Mezirow was influenced by constructivist thinkers, theoretic constructs described by Mezirow have in term had an impact upon the elaboration of constructivist thought. Mezirow refers to our personal paradigm or frame of reference as a 'meaning perspective'. As an adult matures, meaning perspectives should develop in a broader, more integrative and therefore, abstract way. This process occurs through experience. Each new experience is filtered through this system and becomes either assimilated and accommodated within the existing meaning systems or becomes a trigger of change through the creation of disequilibrium. When a new situation challenges existing meaning systems, reassessment

must occur. These dilemmas are commonplace in our lives, and therefore, social and personal situations for which no ready solution exists must be resolved.

Mezirow's explanation of learning is not unlike Piaget's description of assimilation and accommodation as a method of the development of schemata. In both explanations, prior knowledge is the primary mediation factor of learning, and elaboration of information would depend upon the use of existing knowledge which is already stored in long term memory. Both Piaget and Mezirow contend that change is motivated by a state of disequilibrium resulting from information that cannot be assimilated into existing structures. Therefore, the relationship between prior knowledge and subsequent learning is constantly undergoing modification.

Vygotsky's theory of language and cognitive development added a social dimension to constructivism. According to Wertsch (1985):

> The three themes which form the core of Vygotsky's theoretic framework are: (1) a reliance on a genetic or developmental method; (2) the claim that higher mental processes in the individual have their origin in social processes; (3) the claim that mental process can be understood only if we understand the tools and signs that mediate them (p. 14).

Developing a Sovietized approach to psychology during Lenin's rule, Vygotsky's work evolved from a framework of historical materialism in which social change had both directional and dynamic characteristics. Therefore, social change is not a fixed category but one which actively changes historically in a directional way. According to Vygotsky (1978) "Human learning presupposes a specific social nature and a process by which children grow into the intellectual life of those around them" (p. 89). This growth is accomplished through a process of assisted learning within the Zone of Proximal Development. Vygotsky defined this developmental zone as "the distance between the actual development level as determined

by independent problem solving and the level of potential development as determined through problem solving under adult guidance or collaboration with more capable peers" (p. 89). Learning in this sense must have a social dimension and is not a solo performance considered without context. Mental processes are mediated by tools which are speech, and semiotic signs which is language. Learning involves the internalization of semiotic signs which were originally witnessed and practiced in a social setting. This represents one of the basic differences between the thought of Piaget and Vygotsky; however, both Piaget and Vygotsky view intellect as an adaptive function which is fostered through social interaction.

Emergence of Constructivism

Prawat (1995) stated that " once again, we are in the midst of a major educational reform effort that pits progressives, who favor an activity-oriented child-centered approach to schooling, against conservatives, who advocate a more traditional, no-nonsense approach" (p. 13). The theoretic rationale for this shift is the emergent focus on constructivism. According to Phillips (1995) the source of confusion which pervades analysis of constructivist thinking stems from the theoretic focal point and also from the complexity of constructivist thought. Schunk (1996) stated that constructivism can be expressed by three perspectives: exogenous constructivism which posits that knowledge represents a reconstruction of the external world; endogenous constructivism which focuses on the elaboration of mental structures; and dialectical constructivism which holds that knowledge is derived through interaction between persons and their environment (p. 209). While some constructivists focus on the cognitive content of individual learners, others focus on socio-political factors of learning through the development of knowledge within the public subject matter domains or within communities, for example, feminist epistemology. Constructivists view learning from both individual and socio-political perspectives. The basic framework for individual learning through constructivism evolved

from the theories of Piaget and Vygotsky. The tenets of constructivism are not new but represent an adaptation and merging of the ideas of both Piaget and Vygotsky to meet present-day educational needs.

What environmental factors have contributed to the evolution of constructivism ? In recent years, technological innovation and a dramatic increase in information available to students has shown that the traditional role of the school with its traditional methods of instruction do not meet the education needs of our rapidly changing technological society. Instructional methods must be modified so that students can meet the challenges of their environment. According to Honebein et al. (1991):

> We find two classes of complaints about the educational system. The first complaint is that test scores are declining and that our test scores in science and math are below those of almost every developed country in the world. The second complaint is that students are not prepared for the real world (p. 89).

Educational research findings point to the importance of what students learn; the importance of how they learn and also in what type of environment students best learn. Constructivists question the idea that knowledge acquisition can be transmitted directly from teacher to student. In New Zealand, Nuthall & Alton-Lee (1990) performed a series of studies to discover what and how students learn. Some of their findings indicate that: students learn very different things from the same lesson; that the quantity of academic time was closely related to learning; visual demonstration promoted significant recall; and that students' prior knowledge in a subject area shaped student learning. They concluded that students must have, not only the resources with which to learn, but also the opportunity to use these resources. Furthermore, students must actively take advantage of the learning situation. Constructivists contend that education must be redesigned to become more student oriented and to help students become more effective, motivated learners. According to the

Presidential Task Force Report on Psychology in Education (1993), student-centered learning can best be supported through the application of constructivist learning principles.

Constructivism: A theory of learning

Constructivist tenets differ from the assumptions of the traditional objectivist conceptions of learning since objectivism focuses on the object of learning while constructivism focuses on the process by which the learner comes to know. We no longer believe that individuals come into the world with pre-formed cognitive data and systems for the manipulation of this data, nor do we believe that knowledge is unaffected by personal perception. While humans are born with some innate knowledge, the majority of the methods of inquiry are actively constructed in an individual and social way.

How do constructivist theorists view the process of individual learning? Perkins (1991) stated, "Learners do not just take in and store up given information. They make tentative interpretations of experience and go on to elaborate and test those interpretations" (p. 20). Learning takes place through a process of forming, testing and elaborating mental structures. Meaning is indexed by experience. The learner interprets information in a personal way in order to build up an internal representation of knowledge. The learning process can then be defined as a system of problem solving based upon a personal perception of the reality involved. The mind becomes the builder of symbolic representations which are interpreted and elaborated upon by the learner. Winn (1991) posited that knowledge acquisition is dynamic rather than static, multidimensional rather than linear, and systemic rather than systematic. As a result of the process of knowledge construction, the learner will be able to construct interpretations of the knowledge from multiple perspectives. Furthermore, the learner will, not only be able to develop and defend his/her own interpretation of this knowledge, but will also be aware of and be able to manipulate the whole process.

One common misconception of constructivist theory is that every learning situation is interpreted in a unique way. That each learner interprets reality in a personal way is true; however, that this results in a unique personal reality for every individual is questionable. Since interpretation of the physical world is based ,in part, upon universally accepted principles, the uniqueness of an individual's interpretations is limited by these principles. According to Jonassen (1994):

> A reasonable response to that idea is the Gibsonian perspective that contends that there exists a physical world that is subject to physical laws that we all know in pretty much the same way because those physical laws are perceivable by humans beliefs and biases" (p. 35).

Constructivists also view learning from a social perspective, with reality shared through a process of social discourse. Constructivist ideas are based on a contextual world view which purports that since the environment undergoes perpetual change, there is never a final theory but a theory which is always in the process of evolution.

Constructivism: Structure for computer-based instructional design

From examination of how the constructivist ideas for individual learning can be implemented in the design of computer-based learning environments, it is evident that constuctivists do not present a unified point of view; even though there is agreement on some key issues. Focus is either on constructivism as a learning theory or on constructivism as a set of instructional design guidelines; however, both viewpoints support the development of open learning systems. Open learning systems must be need driven, learner-initiated and conceptually and intellectually engaging. While technology can support open learning and the acquisition of advanced knowledge, constructivism can provide both the

theoretic and design foundations for this development. The viewpoints of several constructivists and their contributions to the development of computer-based instruction will be presented. The key similarities from their work will be identified.

Constructivist instruction, from a learning theory perspective, focuses on how we learn and what it means to understand. Meaning is constructed and occurs in context. No restrictions are made on the method of instruction. For example, drill and practice could be used as long as these exercises were placed within the context of the larger problem and the learner could transfer these skills to a broader situation. This orientation can clearly be seen in the work of Honebein,et al. (1991), Duffy & Bednar (1991), and Cognition and Technology Group at Vanderbilt University (1991) in the following examples of their computer-based instructional programs.

Constructivism as a learning theory was the focus used by the Cognition and Technology Group (1991) at Vanderbilt for the development of the Jasper Series. Developed for fifth and six grade students, the Jasper Woodbury Series contained paired or conceptually related episodes designed to teach mathematical principles. Using a narrated video format, the students were motivated in a participative environment to generate solutions to the problems which were presented at the end of each episode. These solutions could then be generalized to other situations. A high level of transfer of learning resulted from these lessons. The Jasper Series was based on a theoretical framework which stressed the use of meaningful problem solving within an anchored instructional format. According to the Cognition and Technology Group (1992), "When people learn new information in the context of meaningful activities, they are more likely to perceive this information as tools rather than as arbitrary sets of procedures and facts" (p. 137). Therefore, new knowledge which is anchored within a meaningful context could be actively used and would not be inert knowledge. Inert knowledge is that knowledge which can be actively recalled upon request, but not used for problem solving situations even though this knowledge might be relevant to the problem solution.

Using the learning of concepts as the focal point for a computer-based lesson was implemented by Duffy and Bednar (1991). This was done through the use of hypertext. Traditionally, history is taught through the presentation of facts, dates, personal information, trends and theories by means of lecture, discussion groups or paper assignments. Duffy and Bednar provided an alternate method of presentation. They developed a database with hypertext options containing original documents which pertained to a particular period of history. Students were presented with a series of problem solving exercises and by accessing this database, relevant information needed for problem solution was obtained. This process is similar to the methods employed by many detectives when attempting to solve a mystery. Student evaluation was based upon the students ability to provide a rationale for the defense of their solution and the method by which the solution was developed.

Honebein et al. (1991) implemented a constructivist learning framework in the design of a simulation which was used as an instructional environment for young adults. The learning environment was the design of a biotechnology building which was reconstructed by the computer using original building blueprints. Students were able to electronically move through the building in order to determine the solution to ergonomic problems. A data base which contained interview transcripts from both the builders and the users of the building was developed for the students' use. At the beginning of the program, the instructor performed a think aloud problem discovery and solution session and at the conclusion of the program, each student was required to record their problem with its solution in a common reference file. By using this file, students could electronically collaborate with other students. In these examples, the development of the learning environment format was secondary to the focus on the method and meaning of learning.

Looking at constructivism as a set of instructional strategies which can be used to create open learning systems, Jonassen (1991), Brown (1989), and Spiro et al. (1991) advocate instructional design using anchored instruction and a problem solving technique

for advanced knowledge acquisition. Lesson design is focused on the format or environment in which knowledge is constructed. Learning environments should provide information for learners which will stimulate the need to learn. Furthermore, these environments should provide cognitive learning tools with which the information can be organized and manipulated by the learner. The learning format within these environments should be case-based or contextual and presentation should be from a variety of perspectives Tasks which are thought to be difficult when attempted in a decontextualized environment become intuitive in a functional, full stimulus environment. Both the physical context for learning and the activities of the learner determine how something is understood, and therefore, learned. Jonassen (1991) stated that "the most effective learning contexts are those which are problem or case-based, that immerse the learner in the situation requiring him or her to acquire skills or knowledge in order to solve the problem or manipulate the situation" (p. 235). According to Jonassen (1994), "The design of instruction is embodied in the learning versus instruction distinction" (p. 35). The focus should not be on the accomplishment of a pre-determined objective as is the case with mastery learning. Instead, Jonassen stated that "Constructivists emphasize the design of learning environments rather than instructional sequences. These learning environments should not be designed by predetermined sequence of instruction but rather by providing a supportive environment from which environmental interpretation can be made" (p. 35).

The goal of instruction should be to provide a level of assistance that will eventually result in independent performance. Jonassen further stated that learning within a constructivist environment is advanced through the use of a case-based format for the study of real-world tasks. This format is presented through the use of anchored instruction; through collaboration between both students and the teacher for the development of multiple perspectives; and through construction, based on an internal process, social negotiation and exploration of real world situations. Instruction should be process oriented rather than product oriented. The work of Brown (1989), Spiro et al. (1991) and Jonassen (1991) offer

examples of how aspects of open learning systems can be created using constructivism as a set of instructional guidelines.

Anchored instruction allows students to find and understand underlying concepts and principles within a meaningful context and to experience the effects of these principles on their understanding and perception. Brown (1989) explained the use of anchored instruction in a mathematics lesson pertaining to the magic square. The mathematical principles of this square are discovered and examined in a traditional classroom setting by working from an initial solution and proceeding towards the problem. Through a cooperative effort, the students begin to understand the nature of the square and its relevant principles. These concepts can also be presented using a computer format which employs a similar theoretic framework.

Cognitive flexibility theory was developed by Spiro (1991) for an effective method of the examination of advanced knowledge structures that occur in abstract and advanced ill-structured domains. These domains were characterized by "case to case irregularity in the knowledge domains" (p. 24). Within ill-structured domains, each case involves, not only a variety of concepts, but also variation between cases of the same type of situation. Therefore, ill-structured knowledge should be acquired experimentally from a wide variety of sources. "Knowledge that will have to be used in many ways, must be taught and mentally represented in many ways" (p. 23). Cognitive flexibility theory presents a viable method of presenting ill-structured information in a way which is a close approximation of the inconsistencies and complexities of a real world. According to cognitive flexibility theory, the use of hypertext within a computer-based environment can create an environmental representation of the natural complexities of the real world by engaging the learner in embedded tasks which must be uncovered using a problem solving technique

Knowledge Acquisition in Nonlinear Environment Series (KANE) was developed from the work of Spiro et al (1991). Literary text with concepts such as "wealth corrupts" were presented to the students using a video format. Students were challenged to develop a

wide range of interpretations for these concepts by extracting relevant information from the video which would illustrate their thinking. "Evaluation of this technique showed that it promoted superior transfer of information to new problem solving situations" (p. 32).

Collaborative knowledge acquisition allows all members of a learning group or class to pool their interpretations of a learning situation. Through this method, individuals can benefit from diverse interpretations and approaches to a common problem. Jonassen (1991) developed an instructional shell which supported collaborative problem solving through the use of networked computers. According to Jonassen, the structure supported topic-oriented seminars by attaching hypertext links to content related nodes for the premises, assumptions, processes and content of the argument. To each of these links a personal representation of ideas was added by the learners thus creating a collaborative compilation of information in a hypertext format. "The purpose of this collaborative text was to force learners into interrelating content within a domain and to take personal positions with regard to issues" (p. 240).

Theoretic Implications

One implication for the use of a constructivist design structure is that learning should focus on the construction of knowledge and not on reproduction of information. In order to do this, instructional design should be structured to result in a learning outcome which reflects the integration of higher level knowledge structures and cognitive strategies. Secondly, authentic tasks should be presented which closely approximate real world situations, for example, case studies. These tasks should be presented in a holistic rather than atomistic manner. Thirdly, reflective practice should be fostered. Finally, tasks should be presented in a multiplicity of ways within relevant contexts. Instruction must be contextualized in such a way that relevant mental structures are activated, and that the learner

is engaged in meaningful problem solving situations. Instruction which is embedded in relevant context produces a higher degree of knowledge retention and knowledge transfer.

Tools that support learning

Knuth & Cunningham (1991) stated that there are three components of a learning environment which can be well supported by tools: information, process and reflexivity. (p. 177). The first component, information, deals with the facts or concepts which the learner is required to assimilate during the course of study. The second component, process, refers to the cognitive processes which are required to engage the learner in the learning task and the third component, reflexivity refers to the ability to be consciously aware of one's own beliefs. Kozma (1992) contended that cognitive tools aid learning by:

> Making large amounts of information available for the learner's use, thus supplementing working-term memory; making it easy to retrieve relevant previously learned information and making it simultaneously available along with current information; prompting the learner to structure, integrate and interconnect new ideas with previous ones; providing for self testing;providing for easy movement, consolidation and restructuring of information (p. 26).

An example of a useful tool for cognitive representation is: Learning Tool (Kozma & Van Roekel 1990), an application which converts outlined information into a concept map format. This application is designed to facilitate concept mapping. By using Learning Tool, the learner can convey abstract ideas by iconic representation so that he/she can manipulate, organize and interrelated these ideas. By using this technique, new knowledge can become integrated with existing knowledge.

Eisner (1993) stated that:

> Representation [of concepts] is the process of transforming the contents of consciousness into a public form so that they can be stabilized, inspected, edited and shared with others. Representation is what confers a public, social dimension to cognition. Meaning is shaped by the form in which it [the concept] appears (p. 6).

Structural knowledge representation generates an indication of the present state of a learner's knowledge. A concept map is one method of knowledge representation. Concept maps are also referred to as knowledge maps or semantic maps in learning literature. "A knowledge map is a two dimensional representation of information. Words are contained in nodes and are connected by namable links. The links help to specify the relationships between nodes and add structure and organization to the map" (Rewey et al, 1992, p. 93).

Concept maps are developed by extracting concepts, which are the basic unit of a map, and their relationships from a text or other content, plotting these concepts as a two dimensional representation on either paper or computer screen and finally of naming the relationships between these concepts. Semantic networks can be used to capture the changing salience of concepts over time and the difference between novice and expert knowledge representations.

There are three common types of maps: spider or cluster maps, chain maps and hierarchy maps. When the information to be mapped is declarative, either spider or hierarchical maps should be used; however, if there is a time sequence involved, then a chain map may be more effective. Procedural information is best handled through use of the chain map. Relationships between concepts may or may not be named. The relationship name, if used, is entered on a legend. When several relationships are included in one map, concept properties emerge. The information in maps can be arranged either horizontally or

vertically. Jonassen (1995) recommended the use of semantic maps for tasks that involve learning or classifying concepts rather than for tasks that involve procedures and principles.

Research has been conducted with a variety of content, and several age groupings. Holley and Dansereau (1984) reported on several studies which they and their colleagues conducted. They conducted a study in which they trained undergraduates in the use of mapping using several passages of about 500-1 000 words in length. After the training period, the students used mapping to study a 3 000 word passage from a geology text. The control group was asked to use their normal method of study. After a five day period, the students were tested. The mapping group recalled significantly more main ideas then did the control group. Dansereau et al. (1989) confirmed this finding in a later investigation when he concluded that "Knowledge maps enhance recall in comparison to texts. This enhancement is most potent at the level of main ideas" (p. 609). Holley and Dansereau (1984) also reported that training in mapping has been useful in graduate courses and independent studies courses. In independent study classes students generated maps of reading material to be discussed with their instructor.

O'Donnell (1994) studied 28 female students age 20 years. A pre-experimental questionnaire was given to assess prior knowledge. One session of mapping training of 60 minute duration and a Delta Vocabulary Test were administered as a pre-test. The sample was divided into two groups: one group used vertically organized maps and the second group used horizontal maps. The results of the investigation indicated that low vocabulary learners in either group profited from use of mapping. The low vocabulary learners performed at the same level as high vocabulary learners when the information maps were organized in a vertical manner. Dennet (1991) confirmed this finding.

Bean et al. (1986) worked with tenth grade high school history students who were given preliminary training in mapping with an emphasis on cause and effect relationships. Students were also given a list of decision options which might have been available to a historical figure. This information was used by the students to make historical predictions.

Training in mapping and the use of options enabled the student to make their prediction without the use of the option list but directly from their own concept maps.

At the core of constructivism is the notion that the learner should engage in active manipulation of information to organize and make sense of that information. A useful learning strategy and tool which can provide a personal representation of knowledge and the way in which an individual perceives his/her environment is through the method of graphic representation of concepts, concept mapping. Moore & Readence (1984) indicated that concept mapping appeared to be especially useful when students constructed concept maps after and during study and when the establishment of the interrelationships between concepts was the focus of their study. Concept mapping can also be developed electronically using Learning Tool (Kozma & Van Roekel, 1990), an application which converts outlined information into a concept map format.

Chapter 3

Research Method

The computer-based instruction program, Canada Meets the World, was developed with a major focus on active learning with real world problem situations and constructivist learning theory as a conceptual framework. Following constructivist tenets it is assumed that people are active learners who learn best within a learning environment where integrated topics are studied from various perspectives and where these topics are rooted or situated within a meaningful, real world context. Even though some universal interpretation of the world is assumed, personal learning occurs through manipulation and organization of information. Personal perception and cultural values influence this process. Furthermore, learning is enhanced through social interaction or collaboration. These learning principles are incorporated throughout the Canada Meets the World.

Canada Meets the World was developed for a Macintosh computer with a twelve inch monitor screen. Alessi and Trollip (1991) stated that with its release in 1984, Apple's Macintosh provided far better integration of text and graphics, better voice and sound capabilities and permitted the user input through the use of the mouse. Macintosh was chosen for its user friendly potential so that computer training time needed for effective use of the computer by learners would be reduced. Also, Macintosh offers a windowed environment in which text and graphics can be easily integrated.

The program was designed using Authorware Professional 2.2 which is an icon-based authoring system. Authorware Professional 2.2 was chosen rather than the newer Authorware Professional 3.0 since the earlier version can be run on a wider range of Macintosh computers, some of which have limited memory capacity and slower processing speeds. This package was also chosen since icon-oriented authoring systems are generally the easiest type of authoring system to use, yet come close to code-oriented systems in

power. Icon-oriented systems are most adequate for the novice CBI developer, moreover, less time is needed to design and develop instructional material using icon-based authoring systems.

The design environment of Authorware Professional uses many of the tenets of constructivism. Using Autherware Professional, lessons are developed by creation of flow charts as shown in figure 1. These flow charts facilitate the reorganization and manipulation of lesson components during the design process. The lesson structure can easily be viewed as a complete unit.

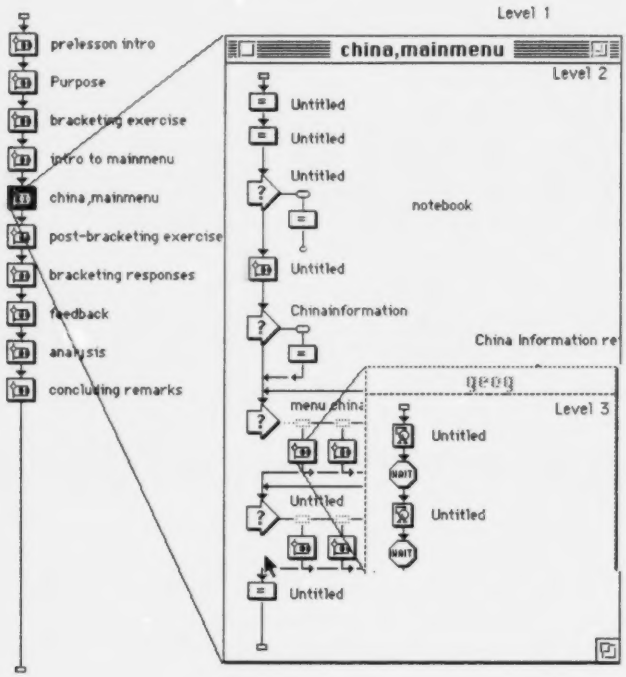

Figure 1. Portion of an Authorware flowchart

Details such as graphics, text, animations sound or the control of other devices and applications can be added through the use of specific types of icons or calculations available for inclusion into the flow chart. Design time can be saved by the creation of models for

shared procedures within the lesson. Also since the lesson structure is iconically represented, pre-lesson planning time is reduced and program debugging is facilitated.

Authorware Professional has application support capability through the use of the system function, Jump Out Return, which allows the user to launch a external application and subsequently return to the lesson at the point from which the jump was made. This procedure is programmed by using a calculation icon as shown in Figure 2.

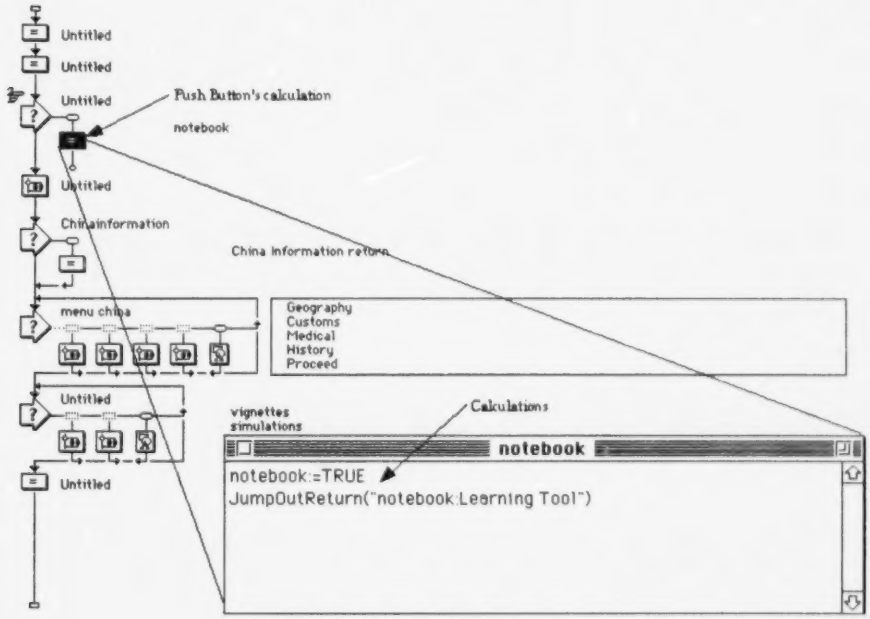

Figure 2 Jump Out Return

The Learning Tool, an application which creates concept maps and Simple Text, a word processing application, were used as cognitive tools to promote active learning and to provide the user with the ability to actively manipulate and organize information in an individual way. Learning Tool, (113K), and Simple text, (54K), are small programs which can be run on most Macintosh computers. Heeren and Kommers (1992) contend that "using a computer application for concept mapping has advantages over the use of paper such as:

facilities to revise concept maps easily and the facilities to stimulate the use of learning strategies" (p.86). Using Learning Tool, abstract concepts are represented in an iconic, two dimensional way. Since knowledge is represented in both graphic and text forms, retention and retrieval from long term memory are facilitated. Learning Tool also contains features designed for self testing and the user can perform multiple-term searches. Information can also be cut and pasted across multiple "notebooks" and since several detail cards can remain open at the same time, working memory is enhanced when using this feature.

When Learning Tool is first launched, it contains no information and remains empty until the user enters information. Learning Tool is designed to work at three levels: the Master List, an outlining space on which the user records key words; a Map space which contains a "file" for each keyword which is entered on the master list thus creating a concept map and finally a "detail card" on which both text and graphics can be entered.

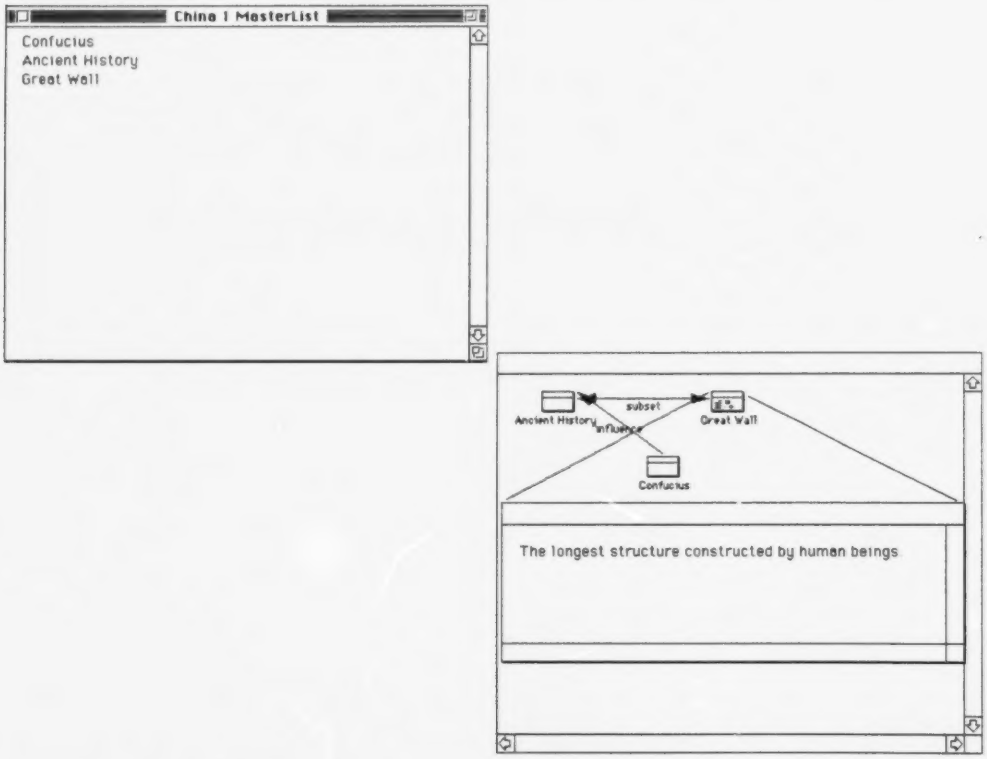

Figure 3. Example of the Learning Tool

At the concept map level, the user can specify relationships between concepts. Kozma (1992) stated that "The creation and modification of networks is intended to facilitate the learner's integration of new information with previous knowledge, and promote the creation of new knowledge as the understanding of relationships among concepts evolves" (p. 27). Therefore, the process of knowledge construction is enhanced and the learner is actively engaged in the learning process.

The inclusion of a word processing package, Simple Text, allows the student to record, edit and print personal reflections and ideas which develop while working with the program. The capacity of a learner to store information is limited within working memory and this information must be frequently refreshed. The availability of a tool with which to record, organized, interrelate thoughts should expand the capacity of working memory.

Canada Meets the World is divided into five sections, an introduction, a pre-lesson exercise, China topics, study aids, and a post-lesson exercise. The first section, introduction, defines the learning environment, China, using an audio, graphic and statistical presentation. At the end of the introductory presentation, the learner must enter his/her name. This entry creates and names a personal notes file for the learner. A pre-lesson exercise follows the introductory section of the lesson. This section is composed of a bracketing exercise containing five questions, which is used to establish the learner's pre-lesson cultural understanding and a cultural chart for the learner's personal culture. By working through this section of the lesson, the learner is actively interacting with the computer.

In section entitled China Information, information is presented using a topical format. A sample page form the history section is shown in Figure 4. By clicking with the mouse on the proceed button, the study aid section of the lesson is available. This section is composed of vignettes which are culturally-based dialog segments followed by questions which are designed to focus learner reflection and a simulation exercise. The final section

of the lesson is composed of post lesson exercises. In these exercises the learner will complete both a post lesson bracketing exercise and a Chinese culture chart

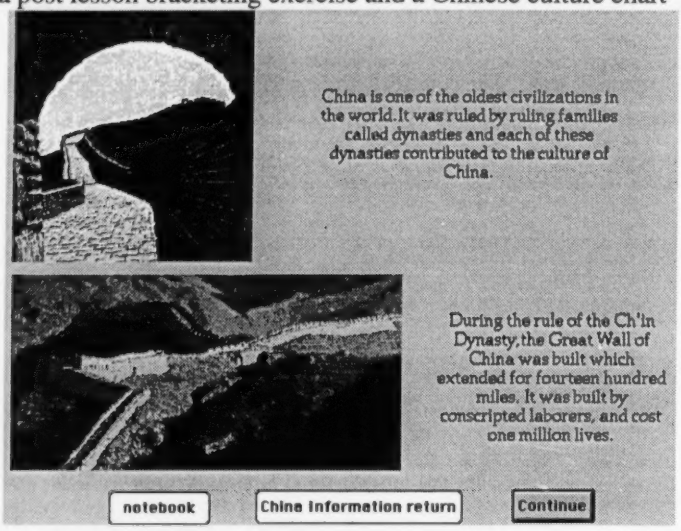
China is one of the oldest civilizations in the world. It was ruled by ruling families called dynasties and each of these dynasties contributed to the culture of China.
During the rule of the Ch'in Dynasty, the Great Wall of China was built which extended for fourteen hundred miles. It was built by conscripted laborers, and cost one million lives.
notebook
China Information return
Continue

Figure 4. Sample Page from China Information Section

Throughout the China Information section, the learner is asked to reflect upon the information which is presented. This exercise allows the student to develop relationships between ideas. A sample page from the History section as shown in Figure 5 typifies a reflection exercise.

Analyze the following:

Learning theory states that people base present learning on past experiences. How can this effect a Chinese person's adjustment to Canadian life.

The Communist Government has said that woman are equal partners to their male counterparts. Looking at China's cultural past practices, do you think that this is the norm for all situations?

Figure 5. Time for Reflection

In a constructivist model, the learning process is active, generative and collaborative. Active learning is fostered through use of the China Information section in Canada Meets the World where data is topically presented. Topics presented include history, Chinese immigration statistics, social customs, diet, medical, geography and family. The student can browse through this section using any topical order or amount of study time. The student has full learner control during this section of the lesson. Two cognitive tools, notebook and notes, are available throughout the section. Within notebook the application, Learning Tool, becomes available to the student. Using Learning Tool, the student can create both concept maps and an outline for each topic to be studied. "Note cards" are also available to record details, both text and graphics, for each study topic. These "note cards" can later be shuffled or re-ordered. After study information is recorded in the notebook through use of Learning Tool, information can then be searched, re-ordered and manipulated to accommodate the student's individual learning needs and perceptions. The second cognitive tool, notes, is available. Notes provides an outlet for student reflection and thought throughout the program. Student reflections can be recorded by using the notes feature which is accessed by clicking the notes button located in the lower portion of the screen. These student entries are displayed at the end of the program and a print option is available. By using the features, notes and notebook, the study of the China Information becomes a learning exercise in which the learner plays an active role in the learning process.

The simulation exercise and the vignette case studies extend the active learning process to real world contextual problems. The simulation exercise provides an opportunity for the student, not only to create an individual study problem, but also, to evaluate the information from both the China Information data base and bibliographic references and use this information to formulate a problem solution. The student can navigate through the village by using hypertext as shown in Figure 6.

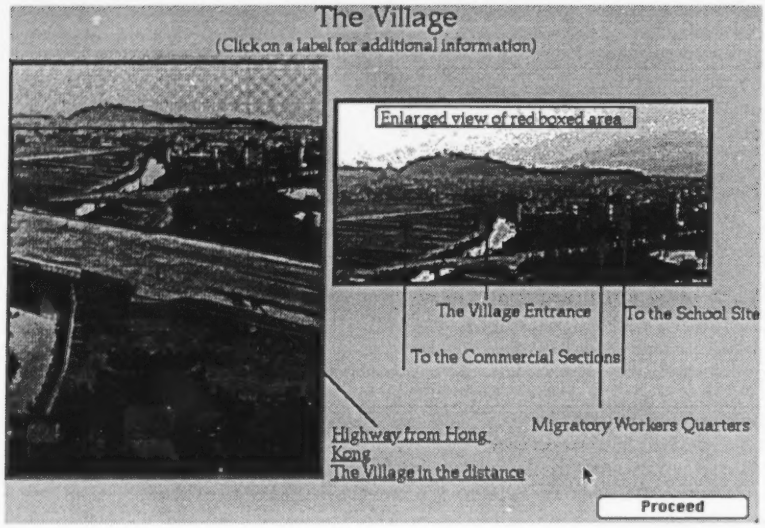

Figure 6. The Village

During the simulation exercise, the notebook option is available to the student. Within the vignette section of Canada Meets the World, the student is presented with a dialog which is followed by questions. These questions are designed to focus student reflections on the issues presented in each dialog . The student must actively reflect upon personal perceptions in order to answer the vignette questions. Using the notes button, the student can enter the answers or solutions for each question. Reference can also be made to the China Information section or bibliographic references during this exercise. A sample vignette dialog is shown in Figure 7.

Vignette 1:

Susan: Yang, it's good to see you again
How do you like your new job?

Yang: It's a very nice place to work. I'm very happy.

Susan: We miss you.

Yang: How is everything at B&G?

Susan: You know, the usual. Aren't you glad you left?

Yang: How are Jan and David?

Questions to think about:

What is the basic dilemma in this vignette?
What cultural factors should Susan be aware of?
Was Susan behaving in a rude manner?

Figure 7. Vignette

A second basic assumption of constructivism is that learning is generative and emerges from individual perception of the information to be learned based upon cultural values and past experiences. This constructivist principle is utilized in the program throughout the bracketing exercise. The student will create a pre-lesson culture chart which will show cultural attitudes and values prior to work with Canada Meets the World. The pre-lesson chart provides a baseline of pre-study attitudes. This exercise is repeated after the study has been completed. From the post-study chart areas of cultural differences become evident. Through a comparison of the pre-bracketing and post-bracketing responses, the student is provided with a comparative assessment of personal attitudinal change and cultural learning. Student awareness of cultural difference is an essential component of the cultural learning process and is necessary for further cultural development and change. A sample of the culture chart can be seen in Figure 8.

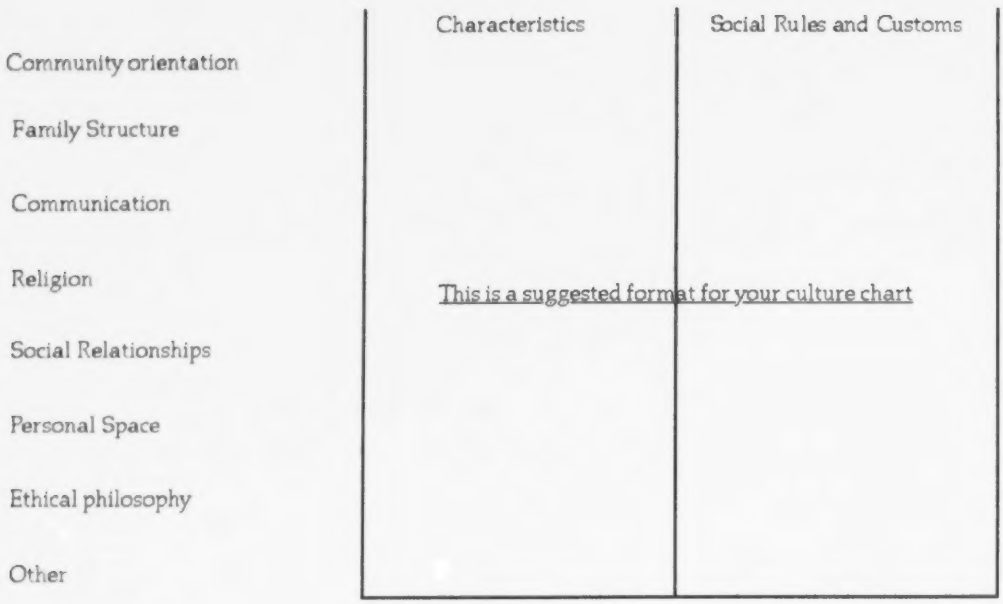

Figure 8. Culture Chart

The third basic assumption of the constructivist learning model is that learning is both a social and collaborative endeavor. The collaboration file which is provided within the simulation exercise provides an electronic means of collaborative learning. An ongoing file will be developed by program users which will contain a cumulative record of all problems with the possible solutions which have been developed by students during their study. By using this record, students can research problems previously done in their interest area and be able to evaluate the relevance of the recorded problems to their personal study. From this file a multiple perspective on the problem topic is made available to the student.

collaborative learning environment provided by the program. An expert, the teacher, walks the student through a possible problem by the use of bubble dialog. Bubble dialog is a technique which employs a graphic or bubble to convey the speech by graphic means. This technique is frequently seen in cartoon dialog. The verbal responses of the teacher in this case are located in the bubble and through this technique the student is visually walked

through a think aloud problem discovery and problem solution technique session. The graphic takes on the quality of social collaboration with a teacher.

The fourth assumption is that information should be viewed from a multiple perspective. The basic design of the program insures that the study of Chinese culture is approached from various perspectives and that learning is reinforced through the use of multiple study formats such as case-based vignettes and contextual problem analysis, the simulation exercise. The multiple perspective approach to learning is further enhanced by the development by students of their own study problems. The development and choice of these problems will be influenced by student cultural background and personal perception.

Chapter 4

Discussion

Two questions emerge from the discussion of the development and use of Canada Meets the World. Can affective computer-based instruction be designed from the assumptions of constructivism? Is the computer an effective cognitive tool ?

Constructivism is an appropriate model for use in the design of computer-based instruction. The assumptions of constructivism provide a flexible structure on which the design of computer-based instruction can be modeled. Current computers possess the necessary flexibility to accommodate lesson development which is neither restricted to atomistic presentation nor preprogrammed instruction as were lessons developed for the teaching machine or earlier computers. Constructivism, as a design structure, opens new horizons for the development of open learning systems. Through use of the constructivist model, a wide range of design components can be effectively incorporated into a lesson. Both programmed instruction which is objective-based, for example, drill and practice, and open learning systems with a real world problem situation format can be employed using this model. Student learning can be evaluated both, from an objectivist perspective through completion of such exercises as drill and practice and from a subjective perspective through evaluation of the personal metacognitive awareness of the student or the student's ability to define and defend his/her learning. Learning with lessons which are based on the constructivist model is limited only by learner creativity while using these lessons.

For the lesson designer, constructivist lesson design presents a formidable challenge. Information must be presented to both challenge and interest the learner. Learning exercises must be designed to incorporate various interpretations of the same idea and a variety of learning formats. Furthermore, social collaboration, which is a basic assumption of constructivist learning, must be incorporated into the learning environment. These design problems provide a unique design challenge.

Can the computer be employed as an effective cognitive tool? The major constraint upon the cognitive system is its limited capacity to store information in working memory. The computer has the capacity to retrieve, store and organize information at speeds far greater than the human capability. Moreover, the computer can be used to extend the learner's working memory and the learner's abilities to manipulate and organization information. Word processing programs such as Simple Text, or knowledge construction tools such as Learning Tool, provide the means for organization of knowledge into long term memory and the means to assist the learner to become aware of cognitive strategies and their use. Canada Meets the World is designed to challenge the user to seek the necessary information from the information data section of the lesson and use this information to explain the vignette situations and simulated role problems. It is designed to promote generative and active learning. This process of knowledge acquisition is a constructive process since newly acquired information is re-organized into existing schemata and existing schemata is reorganized in light of this new information. The process of knowledge construction is enhanced by the use of the computer as a cognitive tool.

Implications for further study

This study was focused on the design of a lesson prototype based upon the tenets of constructivism. The scope of this study is not intended to include the empirical testing of the efficiency of the constructivist approach to learning. The major thrust of this work was toward the design and development of Canada Meets the World. Since this project was designed for use by adult learners, with no design provisions made for its use by children, any empirical validation performed upon this design project could be generalized only to adult learners. Further work is needed to empirically test the validity of this design.

Canada Meets the World was designed to promote self-directed learning. Constructivist tenets appear to serve as an appropriate theoretic framework for the process

of adult learning described in Knowles model of adult learning(Langenbach, 1988). This idea needs further exploration.

Constructivists contend that learning is enhanced through social collaboration. Canada Meets the World can be used as a pre-seminar lesson. Investigation is needed into the feasibility of using computer-based instruction combined with teacher facilitated instruction and group discussion.

References

Alessi, S & Trollip, S. (1991) Computer-based instruction. Englewood Cliffs, NJ: Prentice Hall.

Arlin, P. (1975). Cognitive development in adulthood: A fifth stage? Developmental Psychology, 11, 602-606.

Bayerbach, B. A. (1988). Developing a technical vocabulary on teacher planning: Prob teachers' concept maps. Teaching and Teacher Education, 4, 337-347.

Bean, T., Singer, H., Sorter, J. & Frazee, C. (1986).Teaching students how to make predictions about events in history with a graphic organizer plus options guide. Journal of Reading, 29, 739-745.

Bereiter, C. (1991). Implications of connectionism for thinking about rules. Educational Researcher, 20, 10-16.

Brown, J. S. (1989). Situated cognition and the culture of learning. Educational Researcher, 18, 32-42.

Cognition and Technology Group at Vanderbilt. (1991). Technology and the design of generative learning environments. Education Technology, 31 (5), 34-40.

Cognition and Technology Group at Vanderbilt (1992). An anchored instruction approach to cognitive skills acquisition and intelligent tutoring. In J. Regian & V. Shute (Eds.), Cognitive approaches to automated instruction.Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Cooper, P. (1993) Paradigm shift in designed instruction. Educational Technology, 33 (5), 12-19.

Dansereau, D., Skaggs, L., & Rewey, K. (1989). Effects of scripted cooperation and knowledge maps on the processing of technical material. Journal of Educational Psychology, 81 (4), 604-609.

Dennet, D. (1991). Consciousness Explained. Boston, MA: Brown University Press.

Draper, S. (1992). Gloves of the mind. In P. Kommers, D. Jonassen, & J. Mayes. (Eds.), Cognitive tools for learning. Berlin: Spring-Verlag.

Duffy, T. & Bednar, A. (1991). New implications for instructional technology. Educational Technology, 31 (9), 12-15.

Duffy, T., Lowyck, J., & Jonassen, D. (1991). Designing environments for constructive learning. Berlin: Spring-Verlag.

Eisner, E. (1993). Forms of understanding and the future of educational research. Educational Researcher, 22 (7), 5-11.

Glaser, R. (1984). Education and thinking: The role of knowledge. American Psychologist, 39, 91-104.

Honebein, P., Duffy, T., & Fishman, B. (1991) Constructivism and the design of learning environments: Context and authentic activities for learning. In T. Duffy, J. Lowyck, & D. Jonassen. Designing environments for constructive learning. Berlin: Spring-Verlag.

Holley, C. & Dansereau, D. (1984).The development of spatial learning strategies. In C. Holley & D. Dansereau (Ed), Spatial learning strategies: Techniques applications, and related issues. Orlando,FL: Academic Press.

Jonassen, D. (1990). What are cognitive tools? In P. Kommers, D. Jonassen, & J. Mayes. (Eds.), Cognitive tools for learning. Berlin: Spring-Verlag.

Jonassen, D. (1991). Context is everything. Educational Technology, 31 (9), 28-32.

Jonassen, D. (1991) Constructivist Learning. Educational Technology, 31 (9), 28-32.

Jonassen, D. (1994). Thinking Technology: Toward a constructivist design model. Educational Technology, 35 (4), 34-37.

Jonassen, D., Beissner, K., & Yacci, L. (1995) Structural knowledge: Techniques for representing, conveying and acquiring structural knowledge. Hilllsdale, NJ: Lawrence Erlbaum Associates.

Knuth, R., & Cunningham, D. (1991). Tools for constructivism. In T. Duffy, J. Lowyck & D. Jonassen. (Eds), Designing environments of constructive learning. Berlin: Spring-Verlag.

Kommers, P., Jonassen, D., & Mayes, J. (1990). Cognitive tools for learning. Berlin: Spring-Verlag.

Kozma, R., & Var Rockel, J. (1991). Learning Tool {Computer Program}. Santa Barbara, CA: Intellimation.

Kozma, R. (1992). Constructing knowledge with learning tool. In P. Kommers, D. Jonassen, & J. Mayes. (Eds.), Cognitive tools for learning. Berlin: Spring-Verlag.

Langenbach, M. (1988). Curriculum models in adult education. Malabas:Kreiger Publishing.

Mezirow, J. (1978). Perspective transformation. Adult Education, 28 (2), 100-110.

McClelland, J. (1988). Connectionist models and psychological evidence. Journal of Memory and Language, 27, 107-123.

Moore, D., & Readence, J. (1984). A quantitative and qualitative review of graphic organizer research. Journal of Educational Research, 78, 11-17.

Nuthall, G., & Alton-Lee, A. (1990). Research on teaching and learning: A theory of student knowledge in learning: Thirty years of change. Elementary School Journal, 90 546-570.

O'Donnell, A. (1994). Learning from knowledge maps: The Effects of map orientation. Contemporary Educational Psychology, 19, 33-44.

Perkins, D. (1991). Technology meets constructivism: Do they make a match. Educational Technology, 31 (5), 18-23.

Piaget, J. (1985). The equilibrium of cognitive structures. Chicago, IL: University Press.

Presidential Task Force on Psychology in Education (1993). Learner-centered psychological principles: Guidelines for school redesign and reform. Washington D.C: American Psychological Association.

Rewey, K., Dansereau, D., Skaggs, L., & Pitre, U. (1992). Scripted cooperation and knowledge map supplements: Effects on the recall of biological and statistical information. Journal of Experimental Education, 60 (2), 93-107.

Schunk, D. H. (1996). Learning theories (2nd Edition). Englewood, NJ: Prentice Hall Inc.

Spiro, R., Feltovich, P., Jacobson, M., & Coulson, R. (1991) Cognitive flexibility, constructivism and hypertext. Educational Technology, 31 (5), 24-33.

Surber, J. (1984). Mapping as a testing and diagnostic device. In C. Holley & D. Dansereau (Eds.), Spatial learning strategies: Techniques, applications and related issues. Orlando,FL: Academic Books.

West, C., Farmer, J. & Wolff, P. (1991) Instructional design implications from cognitive science. Englewood, NJ: Prentice Hall.

Winn, W. (1991). The assumptions of constructivism and instructional design. Education Technology, 31 (5), 35-40.

Appendix

The computer-based instructional program, Canada Meets the World.